FORMULATING X-RAY TECHNICS

By

John B. Cahoon, Jr., R. T.

To-
Mother & Dad
Your son,
Johnny

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John B. Cahoon, Jr., R. T.

Instructor, X-Ray Technology, Department of Radiology, Technical Division, Duke University School of Medicine

Chief X-Ray Technician, Clinic X-Ray Section, Duke Hospital

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PREFACE

Since the presentation of the refresher course, "Radiographic Exposure Problems and Its Problems in Formulating Technic Charts," at the 20th annual meeting of the American Society of X-ray Technicians held in Minneapolis, Minnesota, June 1948, we have had numerous requests for a printed manual of the course on "Formulating Technic Charts."

In acknowledgement of my indebtedness to the many people interested in X-ray Technology who have generously contributed toward the production of this manual, I would like to express my personal thanks to the following for their advice: Dr. R. J. Reeves, Dr. W. C. Davison, Dr. George Baylin, Dr. Leo Rigler, Dr. D. A. Allen, Dr. Darmon Rhinehart, Dr. L. R. Sante, Mr. W. S. Cornwell, Mr. Arthur Fuchs, Mr. John Russell, Mr. Gene Stober, Mr. H. L. Hassell, Mr. Flinton Carden, Mr. Elon Clark, Mr. Bob Blake, Mr. Neeley Webster, Mr. H. C. Pickett, Mr. O. A. Parks, Mr. H. C. Mickey, Mr. F. Ross Porter, Miss Ruth McMillan, Miss Esther Zutter, Dr. Leslie Hohman, Dr. Grant Taylor, Dr. Lennox Baker.

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No attempt is made to set forth definite exposure technics. Specific exposure factors are conditioned upon the particular equipment that is employed.

The author hopes this outline will prove useful, and to that end he would greatly appreciate suggestions for improvements from those who use it.

JOHN B. CAHOON, JR.

Section I

THE RADIOGRAPH

A radiograph is essentially a "shadowgraph" in which X-rays emanating from the focal spot of the tube pass through the object and are recorded on the photographic film. The radiograph, therefore, gives a record of anatomic densities, and its inherent diagnostic quality is determined by a number of important factors.

To constantly produce and duplicate radiographs of high diagnostic quality requires considerable skill, experience, and a thorough knowledge of the fundamental principles underlying X-ray techniques. Briefly, the outstanding factors having largely to do with the quality of the radiograph may be summarized as follows: contrast, detail, distortion, and density.

There is some difference of opinion as to which type of exposure constitutes the ideal radiograph, but most workers agree on the importance of securing a radiograph that shows the finest definition of bone and soft tissue structures, ample diagnostic contrast, a minimum of distortion and sufficient density to bring out these qualities. When these four factors are duly considered and properly taken into consideration, it will be seen that they govern completely the general radiographic quality and diagnostic worth of the exposed film. Although these four factors are components of the radiographic quality as a whole, they are entirely independent of one another, and with suitable apparatus and accessories may be separately controlled and consistently duplicated at all times.

DISTORTION

Distortion may be of two types.

1. *Magnified:* This type of distortion results when the film distance (i.e. the distance between a plane of the part under consideration and the film) is great in proportion to the focal film distance.
2. *True:* The unequal magnification of various portions of a plane of the part under consideration. This type of distortion may be produced because of malalignment of the tube in relation to the film and part.

Distortion or unsharpness of image may be lessened by the following:

1. Distance
   a. Short object film distance—less distortion

b. Great target film distance—less distortion

2. Proper centering
3. Focal spot size (small)

DETAIL

Detail refers to the sharpness of various contour lines and the clear cut, clearly defined lines of cancellous structures of the bones.

Detail is affected by the following:

1. Focal spot—small focal point permits sharper detail.
2. Distance—object film distance should be short, target film distance should be great.
3. Screen contact—perfect contact absolutely necessary, non screen exposures whenever possible.
4. Lack of motion—of tube, film, or of patient (immobilize whenever possible or practicable).
5. Short exposure.
6. Lack of Film Fog—Secondary radiation fog decreased by cones, diaphragms, fresh film, proper darkroom procedures.

Detail is decreased by:

1. Distortion.
2. Movement of the part, film, or tube.
3. Use of large effective focal spot.
4. Use of intensifying screens.
5. Poor intensifying screen film contact.

With only one exception all of the factors controlling detail may be considered mechanical or fixed factors. Motion is the exception.

The greater the focal film distance and the closer the object film distance, the sharper the resultant detail in the radiograph. The effect of focal film distance as well as object film distance upon detail sharpness decreases as the size of the tube focal spot is decreased.

CONTRAST

Contrast is the relative degree of blackness of the black portion of the film as compared with whiteness of the white portions.

It is decreased by the following:

1. Use of a film which has the emulsion with a long scale gradation.
2. Increasing the kilovoltage.
3. Using slow type screens intensifying or cardboard holders rather than fast screens.

4. Secondary radiation which is increased in proportion to the thickness of the part and increases in kilovoltage. The effects of radiation may be reduced by the use of a grid, cones, and diaphragms.
5. Over-exposure, shortening in the time of development, or the use of cold developer.

MOTION

Motion of the part will result in a loss of detail, but this loss may be overcome with proper immobilization by means of immobilizing bands, cones, and sandbags. In those regions where immobilization is difficult and maximum sharpness is desired, one would use a short exposure time. On all extremities where the thickness of the part is 10 cm. or less it is recommended that non screen exposures be made. The use of intensifying screens detracts somewhat from detail sharpness. However in some examinations the slight loss in detail sharpness caused by intensifying screens is more than compensated for by the shorter exposure time values and finer focus tubes permitted by their use.

DISTANCE

The term distance as commonly used in radiographic work refers to the distance from the target of the X-ray tube to the film. The intensity of X-rays varies inversely to the square as the target film distance is changed. For example, assuming you have an exposure of two seconds, a 25 inch target film distance, and you wish to change the distance to 36 inches, your time would increase according to the inverse square law. 25 squared equals 625. 36 squared equals 1296. Therefore, 625 is to 1296 as 2 is to x or approximately 4.1 seconds.

$$625 : 1296 :: 2 : x$$
$$625x = 2592$$
$$x = 4.1$$

DENSITY

A. The final density of a radiograph is governed by the following:
   1. The total exposure
   2. The degree of development
   3. In standardized technique the development is constant, either three minutes or five minutes at 68°.

B. The total exposure is made up of:
   1. Primary radiation penetrating the part forming the radiographic image.

2. Secondary radiation reaching the film and obscuring the radiographic image.
3. Total photographic fog inherent in the film or produced during the handling or processing. The photographic fog can be minimized by good technique and need never be a problem in a well regulated X-ray department.

Of the above 3 sources of total exposure, the first is the only useful one. The primary radiation reaching the film can be said to produce the desirable "image density." The last two sources of exposure can be said to contribute to the total undesirable "fog density." When fog density can be reduced, the image density must be increased to keep the total density to the degree most desirable.

Factors governing image density

A. The total amount of primary radiation reaching the film.
B. The amount of primary radiation reaching the part minus the amount of primary radiation absorbed by the part.
C. The amount of radiation absorbed by a given part is governed by:
    1. The total quantity of radiation reaching the part
    2. The general quality of the radiation
    3. The thickness of the part
    4. The structure of the part. The structure density, and consequently, the required exposure for a given thickness of part, may vary in different individuals too.
        a. Disuse
        b. Age
        c. General physical condition
        d. Racial characteristics
        e. Pathology
D. The quantity of primary radiation reaching the part is affected by:
    1. Milliamperage
    2. Exposure time
    3. Kilovoltage
    4. Total filtration
    5. Distance (Inverse Square Law)
E. The quality of primary radiation reaching the part is controlled by:
    1. Kilovoltage
    2. Total filtration
    3. Distance (air absorption of long wave lengths)

Section II

PRIME FACTORS IN THE PRODUCTION OF RADIOGRAPHS

There are three so-called prime factors necessary in the production of any radiograph. Two factors, Milliampere seconds and kilovolts peak or penetration, are usually considered the factors controlled by the X-ray machine. The third prime factor presents itself in the question of the region and the thickness or density of this part. To determine the thickness in either inches or centimeters is easy. However, some consideration must be given the opacity of the body parts in different individuals as the density does vary to some extent even though the measured thickness may remain the same.

The term Milliampere seconds is descriptive of the number of milliamperes or the amount of current passing through the X-ray tube for a given period of time. The milliamperes applied to an X-ray tube can be favorably compared with the amount of sunlight necessary to make an exposure with a camera. The radiographic density of a film varies directly with the milliampere seconds.

Milliampere seconds is the product of the milliamperes times the time of exposure in seconds. For example, an exposure of 50 M.A. for 3 seconds would be 150 M.A.S., or an exposure of 75 M.A. for 2 seconds would be 150 M.A.S., or an exposure of 150 M.A. for 1 second would be 150 M.A.S.

The kilovoltage spoken of in peak values as used in X-ray work is sometimes referred to as the penetration factor. It is recommended that the kilovoltage be varied as the thickness of the region to be radiographed varies. A measuring technic is much safer and a more logical starting point from which to select the kilovoltage than the weight or comparative size of the individual.

On the modern machines the K.V.P. output is controlled by the autotransformer. The autotransformer is a winding that, if properly designed, permits one to control the K.V. output in steps of approximately 1 K.V. on the minor and steps of 10 K.V. on the major.

The Primary Exposure Factors

A. For any radiographic problem, the "correct exposure" will require a precise combination of the four prime factors:
    1. Kilovoltage
    2. Milliamperage

3. Exposure time
4. Target film distance

Provided that no other factors in the radiographic problem are changed, the radiographic density may be altered to a predetermined degree by varying any one of the "four prime factors."

B. Since milliamperage is so much a function of tube capacity, it is quite impractical to use it as a variable.

C. Time can be used as a variable with excellent results except where motion is a factor. In all moving parts there is a certain "optimum exposure time" beyond which motion becomes objectionable.

D. Kilovoltage affects both the quality and quantity of X-rays and hence makes an ideal variable for changes in part thickness. This technique is practical only when the autotransformer design permits 1 or 2 K.V. changes to be made.

E. Under average conditions, variations in part thickness will require compensations of 2 K.V. per centimeter with screens and 3 or 5 K.V. per centimeter without screens.

F. Distance can be used as variable, but is recommended only when control limitations and motion make K.V. or time variations impractical. Distance changes cause changes in image magnification with consequent image detail variations.

It is good technique to keep 3 factors constant and vary only the fourth to affect changes in radiographic density.

The Secondary Factors

A. Intensifying screens

Until non screen films were introduced all X-ray film had an emulsion most sensitive to "blue light," the color of the fluorescence of calcium tungstate intensifying screens.

When intensifying screens are used about 90% of the total exposure is effected by "printing the visible image on the intensifying screen onto the X-ray film." Only about 10% of the total exposure is caused by the X-rays striking the film.

When intensifying screens are used the "scale of gradation" of the radiographic image is considerably shortened, hence the radiographic image appears more contrasted. The speed of intensifying screens (i.e. the ratio of exposure time between non screen and screen technique is 5 to 1 (i.e. 10 MAS screen — 50 MAS non screen).

B. The amount of exposure conpensation to be used for cones is governed by:

1. The proportionate decrease in "volume of part" radiated; this is governed by:
   a. The thickness of the part
   b. The size of the cone (divergence)
   c. The target film distance
2. The structure of the part
3. The kilovoltage

In general when using cones, we add from 2 to 10 K.V. in order to compensate for loss of "fog density."

C. The Potter Bucky Diaphragm

When a Potter Bucky Diaphragm is used, the exposure must be increased enough to compensate for

1. A reduction of about 85% in the intensity of the secondary radiation reaching the film.
2. A slight reduction in the intensity of the primary radiation reaching the film, due to the filtration of the table top and the bucky grid. Under average circumstances, a Bucky technique requires at least *3 times as much exposure as non bucky technique.*

Stationary grids require slightly less exposure than that required for a Potter Bucky Diaphragm.

The use of a cone, a diaphragm, or a grid should be considered for any part of the tissues of which are solid and not air-contained, or where there is edema or accumulation of fluids, and particularly when the thickness of the part is 12 cm. or greater.

D. Milliamperage, Time, Distance, and Kilovoltage

1. Milliamperage must necessarily depend upon the capacity of the unit (including the tube capacity) and the requirements of the focal spot dimensions. High milliamperage imposes the requirements of relatively large focal spot dimensions which detract from the sharpness of detail.
2. Time of exposure should be reduced to the minimum to counteract the effects of motion. For all practical considerations, the time of exposure and the milliamperage are interchangeable. The greater the milliamperage, the less will be the time of exposure required and vice versa.

3. Roughly K.V.P. changes might be interolated with respect to M.A.S. values as indicated.

Decrease 10 K.V.P. give 2 times the M.A.S.
″ 13 K.V.P. give 3 times the M.A.S.
″ 15 K.V.P. give 4 times the M.A.S.
″ 18 K.V.P. give 5 times the M.A.S.
″ 28 K.V.P. give 10 times the M.A.S.

Increase 10 K.V.P. give one half the M.A.S.
″ 13 K.V.P. give one third the M.A.S.
″ 15 K.V.P. give one fourth the M.A.S.
″ 18 K.V.P. give one fifth the M.A.S.
″ 28 K.V.P. give one tenth the M.A.S.

Conversion Chart for Radiographic Technic

When a variation from an established technic is found necessary the following chart will enable the operator to maintain a uniformity of radiographic density.

Distance From	*Change To*	*Add or Subtract*
36 inches	42 inches	add 5 KVP
36 ″	48 ″	add 9 KVP
36 ″	54 ″	add 11 KVP
36 ″	60 ″	add 13 KVP
36 ″	72 ″	add 16 KVP
36 ″	30 ″	subtract— 6 KVP
36 ″	24 ″	subtract—11 KVP
36 ″	20 ″	subtract—14 KVP
30 ″	36 ″	add 6 KVP
30 ″	42 ″	add 10 KVP
30 ″	60 ″	add 16 KVP
30 ″	72 ″	add 20 KVP
72 ″	60 ″	subtract— 5 KVP
72 ″	48 ″	subtract—11 KVP
72 ″	42 ″	subtract—13 KVP
72 ″	36 ″	subtract—16 KVP
72 ″	30 ″	subtract—20 KVP

RELATION OF DISTANCE TO MAS

From	*To*
30 Inch Distance— 10 MAS	48 Inches Use 20 MAS
30 Inch Distance—100 MAS	48 Inches Use 200 MAS
30 Inch Distance— 10 MAS	72 Inches Use 55 MAS
30 Inch Distance— 10 MAS	72 Inches Use 40 MAS
30 Inch Distance—100 MAS	72 Inches Use 400 MAS
36 Inch Distance— 20 MAS	72 Inches Use 80 MAS
36 Inch Distance— 20 MAS	48 Inches Use 35 MAS
36 Inch Distance— 50 MAS	42 Inches Use 65 MAS
36 Inch Distance— 50 MAS	48 Inches Use 90 MAS
36 Inch Distance— 50 MAS	60 Inches Use 140 MAS
36 Inch Distance— 10 MAS	30 Inches Use 7 MAS

Section III

GENERAL INSTRUCTIONS, DIAPHRAGMS AND FILTERS

IMMOBILIZATION. Immobilization is one of the most important single factors used in making a successful X-ray exposure, and it is quite often overlooked by many X-ray technicians.

Not only gross movement, but even a fine tremor will destroy detail on X-ray films.

The most useful immobilizing device, one that can be used for almost any purpose, consists of sandbags six to eight inches long and weighing three to five pounds each.

Sandbags will meet most requirements as an immobilizing device, except in cases for which a compression band is best suited as in the examination of the kidneys, viscera, chest and spine.

RESPIRATION. Time spent in carefully instructing the patient as to what he is expected to do will more than repay the energy, effort, and expense in making retakes due to motion on the X-ray film.

Respiration should be suspended when exposures of the lungs, abdominal viscera, sinuses, shoulders, and anterior-posterior views of the spine are made. Radiographs of the lungs should be made at the height of inspiration.

FILM SIZE. The film size for an X-ray examination should be large enough to include the region to be examined and in cases of fractures the film should be large enough to include the joint nearer the site of fracture.

CONES, CYLINDERS, AND DIAPHRAGMS. To limit the rays that strike a part being exposed so that the beam is not much larger than the film being used, employ cones, cylinders, or lead diaphragms inserted in the slot under the tube. If cones and cylinders are not available, lead diaphragms can be made and an assortment of this kind suitable for all purposes kept on hand.

Proper diaphragming reduces scattered radiation to a minimum, giving films of much better contrast and detail. In preparing a set of lead diaphragms, first determine the sizes of the film areas and the distances that are to be used in the department. The anode-diaphragm distances of the tubes with which the diaphragms are to be used must also be determined; this is the distance from the anode to the slot beneath the tube for the reception of the filter, cone, or lead diaphragm. The anode-diaphragm distance is usually six inches. The formula used in finding the size of the diaphragm opening is: anode-diaphragm distance (D) is to the anode-film distance (D^1) as the diaphragm opening (X) is to the film area in length or width (or the area in length or width of the portion to be exposed on the film being used) (L).

Example: An area of 5 square inches, 1 inch wide and 5 inches long, is desired on an 8x10 inch film at a 30 inch anode-film distance and a 6 inch anode-diaphragm distance.

Then,

$$6:30::X:5$$
$$30X = 30$$
$$X = 1 \text{ inch} = \text{length of diaphragm opening}$$

And,

$$6:30::X:1$$
$$30X = 6$$
$$X = 1/5 \text{ of an inch} = \text{width of diaphragm opening}$$

Therefore, the opening of the lead diaphragm would be 1 inch long and 1/5 of an inch wide.

Limiting the port of entry of the X-ray beam in exposing thin parts is of no special importance, but it is of great importance in making exposures of thick parts of the body such as the skull, spine, pelvis, mastoids, sinuses, and abdominal viscera. Cylinders or small cones and diaphragms are very important in making "spot" films.

Compensating Filters

Compensating filters are used when tissues of a part to be examined vary in density. Opaque plastic filters are more selective than the single aluminum filter: and are more applicable when waves of various lengths are to be eliminated. The gradation of the plastic substance applied to the base makes it possible to select or obtain an exposure which will give the penetration necessary for the heavier parts, yet which, through absorption by the filter, will also give satisfactory images of the parts requiring less penetration.

The less dense area of a part to be examined is roentgenographed through the semi-opaque material so that the entire area is uniformly represented on the finished roentgenogram. This material, manufactured by the General Electric X-ray Company, consists of a plastic clay with an oil base mixed with barium sulfate.

Since there is a gradation of thickness in the parts of the body requiring a filter, in constructing the barium plastic filter, plastic is applied with moist fingers to a ½mm aluminum filter. The barium is applied in the thickness desired to cover the parts of highest density.

The process of making the filter is facilitated by first inscribing the opening of the cone on the aluminum filter. The plastic filter may be used for:

(1) AP view of the foot
(2) Os Calcis
(3) Cervical-Dorsal Spine
(4) Lumbar-Dorsal Spine
(5) Placenta
(6) Chest (pathology)

Section IV

ARITHMETIC AND MATHEMATICS

Although there are a great many problems in radiography that have not been reduced to exact mathematics, we are able, at present, to apply a certain amount of mathematics to Radiographic Technique.

Technique conversion can be quite accurately calculated and represents a much more scientific procedure than the old "hunch method" of radiography.

This section progresses step-by-step. All explanations are phrased simply, in language that is easily understood.

Fractions

1—A fraction is part of a unit, such as ½, ¾

A fraction has a numerator and a denominator.

Example: In the fraction ¾, 3 is the numerator, and 4 is the denominator.

In any fraction, the numerator is being divided by the denominator.

Example: The fraction ¾ indicates that 3 is being divided by 4.

2—In solving equations you usually place the unknown on the left and solve for the unknown first.

Example:

$$\frac{a}{b} = \frac{c}{d}$$

If we wish to find "a" it would be written:

$$a = \frac{bc}{d}$$

Which means "a" is equal to "b" times "c" divided by "d."

3—Going back to $\frac{a}{b} = \frac{c}{d}$ the unknown is usually placed on left. If a letter from the right is taken, we place it on the lower left and the letter on the bottom left goes to the upper right.

Examples: $d = \frac{bc}{a}$ $c = \frac{ad}{b}$

4—The word "of" is often used to mean "multiply

Example: ½ of ½ = ½ × ½ = ¼

Decimals

A decimal, which is a number with a decimal point (.), is actually a fraction, the denominator of which is understood to be 10 or some power of 10.

A. The number of digits, or places, after a decimal point determines which power of 10 the denominator is. If there is one digit, the denominator is understood to be 10; if there are two digits, the denominator is understood to be 100, etc.
Example: .7 = 7/ 10, .39 = 39/100, .727 = 727/1000.

B. The addition of zeros after a decimal point does not change the value of the decimal, and if there are zeros only after a decimal point, they may be removed without changing the value of the decimal.
Example: .9 = .90 = .900 and vice versa,
.900 = .90 = .9

C. Since a decimal point is understood to exist after any whole number the addition of any number of zeros after such a decimal point is written in does not change the value of the number.
Example: 6 = 6.0 = 6.00, etc.

D. If a decimal point already exists with digits following it, the addition of any number of zeros after such digits will not change the value of the decimal.
Example: .37 = .370 = .3700, etc.

Per Cents

The per cent sign (%) is a symbol used to indicate percentage, but no operations can be performed with the number to which it is attached. For convenience, then, it is sometimes required to attach a per cent sign, but to perform operations with the number, it is necessary to remove the per cent sign.

A. In general, to add a % sign, multiply the number by 100.
Example: 5 = 500%

B. In general, to remove a % sign, divide the number by 100.
Example: 900% = 9

C. A per cent may be expressed as a decimal or a fraction by dividing it by 100.
Example: 43% = .43
7% = 7/100

D. A decimal may be expressed as a per cent by multiplying it by 100.
Example: .39 = 39%

Ratio

A. A ratio expresses the relationship between two (or more) quantities in terms of numbers. The mark used to indicate ratio is the colon (:) and is read as "is to."
Example: The ratio 6:7 is read "6 is to 7."

B. A ratio represents the function of division. Therefore, any ratio of two terms may be written as a fraction, and any fraction may be written as a ratio.
Example: 7:8 = ⅞
2/5 = 2:5

C. To simplify any complicated ratio of two terms containing fraction, decimals, or per cents:
1. Divide the first term by the second.
2. Convert to a ratio.

Example: Simplify the ratio 5/6:7/8
Solution: 5/6 ÷ 7/8 = 5/6 × 8/7 = 20/21
20/21 = 20:21
The ratio simplified is 20:21

D. There are two main types of ratio problems:
1. Problems in which the ratio is given
2. Problems in which the ratio is not given

E. To solve problems in which the ratio is given:
1. Add the terms in the ratio
2. Divide the total by this sum
3. Multiply each term in the ratio by this quotient

Example: The sum of $360 is to be divided among three people according to the ratio 3:4:5. How much does each one receive?
Solution: 3 + 4 + 5 = 12
$360 ÷ 12 = $30
$30 × 3 = $90, $30 × 4 = $120, $30 × 5 = $150

F. In problems in which the ratio is not given, there is a basic quantity with which all the others are compared.

G. To solve such problems:
1. Assign the ratio value of 1 to the basic quantity
2. With 1 as a basis, compute the ratio values of the other quantities based on the facts given
3. Form a ratio using the ratio values derived
4. Add the terms in the ratio

5. Divide the total by this sum
6. Multiply each term in the ratio by this quotient

Example: A man bought three X-ray machines. The first one cost ¼ more than the second and the third ½ more than the second. He paid $30,000 for the three machines. How much did he pay for each?

Solution: The basic machine is the second one which has the ratio value of 1.

The first machine cost ¼ more than the second; therefore its ratio value is 1¼.

The third machine cost ½ more than the second; therefore its ratio value is 1½.

Ratio of the costs = 1¼ : 1 : 1½
1¼ + 1 + 1½ = 15/4
$30,000 ÷ 15/4 = $8000
$8000 × 1¼ = $10,000
$8000 × 1½ = $12,000
$8000 × 1 = $8000
The first machine cost $10,000
The second machine cost $8000
The third machine cost $12,000

Proportion

A. A proportion indicates the equality of two (or more) ratios.
Example: 2:4 = 5:10 = 6:12 is a proportion.

B. If a proportion contains only four terms, the two outside terms are called *the extremes*, and the two inside terms are called *the means*.
Example: In the proportion 2:3 = 4:6, 2 and 6 are the extremes, and 3 and 4 are the means.

C. In any proportion of four terms, the product of the means equals the product of the extremes.
Example: Relation between milliamperage and time
1. *Rule:* The milliamperage (M) required for a given exposure is inversely proportional to the time (T).
2. *Example:* Suppose that 30 milliamperes (M_1) and an exposure time of ½ second (T_1) have been employed, and it is desired to decrease the exposure time to 1/20 second (T_2). What milliamperage (M_2) would be required?

$M_1 : M_2 :: T_2 : T_1$
$30 : X :: 1/20 : ½$
$1/20\ X = 15$
$X = 300$ milliamperes

$$\frac{X}{20} = \frac{15}{1}$$
$$X = 15 \times 20$$
$$X = 300$$

Transformation or Change in Voltage

The transformation, or change in voltage, is roughly proportional to the ratio of the number of turns in the two coils of a transformer.

Step Up Transformer

The primary coil, which is connected to the alternating supply line of 110 or 220 volts, has relatively few turns; the secondary, which energized by induction from the primary coil, consists of a great number of turns.

Example:

If there are 10 turns in the primary coil and 10,000 in the secondary, an impressed voltage of 100 volts on the primary side would induce 100,000 volts in the secondary circuit, with a corresponding decrease in amperage. If it is assumed that the transformer has an efficiency of 100 per cent, the product of the primary voltage (energy E) and current (intensity I) ($E_1\ I_1$) would equal the product of the same factors in the secondary side ($E_2\ I_2$). Therefore, with a primary voltage of 100 volts and current of 10 amperes, there would be this hypothetical transformation:

$E_1 I_1 = E_2 I_2$ or 100 volts × 10 amperes = 100,000 volts × .010 amperes

In the accepted terminology, the units of electricity of the secondary side would be expressed as 100 *kilovolts* and 10 milliamperes.

OHM'S LAW

When current is transmitted through a conductor, the current of transmission varies directly as the electromotive force (voltage) and inversely as the resistance (Ohmage) of the transmitting circuit.

$$\text{Current} = \frac{\text{electromotive force}}{\text{resistance}}$$

$$\text{In electrical units: Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{In symbols: } I = \frac{E}{R}$$

where I = Intensity of current in amperes
E = Electromotive force in volts
R = Resistance in ohms

If we know the current and resistance and want the electromotive force, we have:

$$E = IR$$

If we know the electromotive force and current and want to calculate the resistance, we have:

$$R = \frac{E}{I}$$

Example:

1—What is the intensity of the current sent through a resistance of 5 ohms by an electromotive force of 110 volts?

$$I = \frac{R}{E} = \frac{5}{110} = 22 \text{ amperes}$$

2—What electromotive force is needed to send a current of 0.03 amperes through a resistance of 1000 ohms?

$$E = IR = 0.03 \times 1000 = 30 \text{ volts}$$

3—Through what resistance will 110 volts send a current of 10 amperes?

$$R = \frac{E}{I} = \frac{110}{10} = 11 \text{ ohms}$$

Developer Tank Capacity

To find the number of gallons of developer required to fill the tank, multiply the width by the length times the depth (in inches), and divide the product by 231.

(231 cubic inches is displaced by one gallon.)

Radiographic Tube Rating

Watt

The Watt is the unit of electric power.

Watts = amperes × volts

Since the watt is a very small unit of power, we commonly use the kilowatt (K.W.) which is 1000 watts.

$$K.W. = \frac{\text{amperes x volts}}{1000}$$

If a rating chart is not available, the approximate milliamperage capacity of an X-ray tube with a given focal spot size may be determined. One square millimeter of tungsten will sustain 200 watts per second. Some radiographic tubes are identified as 2, 4, 6, or 10 KW tubes. The 2 KW tube, has a projected focal spot of 1.7 mm. The kilowatt rating and the permissible kvp and mas for one second may be determined, if the projected effective focal spot, written, (PEFS) is known.

$$\text{KW rating} = \frac{(\text{PEFS}^2 \times 3\tfrac{1}{2}) \times 200}{1000}$$

PEFS^2 equals the dimensions of the projected focal spot, *3½ is a constant value,* which is used to convert the size of the PEFS into the actual focal spot under bombardment. 200 is the wattage sustained by 1 square millimeter of actual focal spot and 1000 is used to convert watts to kw.

$$\frac{1.7^2 \times 3.5 \times 200}{1000} = 2.02 = 2 \text{ kw}$$

If the tube is operated at 80 KV for one second, the maximum milliamperage for a 2kw tube can be determined.

$$P = E \times I$$

P equals power to tube

E equals root mean square voltage

I equals current

Converting 80 kvp to rms voltage equals 80,000 peak volts × .707 = 56,560 volts.

$$I = \frac{P}{E} = \frac{2000}{56{,}560} = .035 = 35 \text{ MA}$$

A 2kw radiographic tube, lacking a tube rating chart may be operated at 80 KVP for one second at 35 M.A.

Checking the Timer

Spinning top method

If a metal top with a single hole at the edge of the disc is radiographed for a fraction of a second while spinning, a series of dots will appear on the film, each representing a single impulse of the alternating current.

There will be one dot for each 1/120 second in a 60 cycle machine.

At 1/10 of a second there should be 12 dots

At 1/20 of a second there should be 6 dots

Section V

"ULTRA-SHARP RADIOGRAPHIC DETAIL"

A Mathematical Analysis of Radiographic Unsharpness

A. THE SHARPNESS (DETAIL) PROBLEM

I. Geometrical unsharpness (uG)

a. The Magnification Factors

1. Target-Film Distance (D)
2. Part-Film Distance (d)

Magnification can be present without detail loss only when the focal spot size is infinitely small. For a given focal spot size and target-film distance, blurring increases as the part-film distance increases.

b. Focal Spot Size (F)

The offending factor in geometrical unsharpness.

As focal spot size is increased with a fixed target-film distance, blurring becomes progressively greater for parts farthest removed from the film.

c. The formula for calculating Geometrical unsharpness:

$$u\,G = \frac{d\,F}{D\text{-}d}$$

II. Motion unsharpness (uM)

a. Any motion (M) occurring in the part will be magnified on the radiograph by the same distance factors that produce image magnification.

b. Formula for calculating Motion unsharpness:

$$u\,M = \frac{D\,M}{D\text{-}d}$$

c. The judicious use of accessories for immobilization and a general trend towards small focal spots and low milliampere, long-time exposures, will result in better general radiography.

d. Short exposures are only necessary where involuntary motion is a factor, or where immobilization is inadequate.

III. Screen unsharpness (S)

a. All intensifying screens show a loss of detail due to halation of the invisible light during the printing of the screen image onto the X-ray emulsion.

b. Fast screen (large crystals) show greatest loss of detail.

c. Approximate unsharpness values of intensifying screens are:

Fast Screens	0.20 mm
Par Speed	0.15 mm
Slow Screens	0.06 mm

d. The above values apply only when the screens are in perfect contact with the film. Loss of contact may result in complete obliteration of otherwise sharp detail.

B. THE SHARPNESS FORMULA

I. Total unsharpness equals Geometrical unsharpness plus Motion unsharpness plus Screen unsharpness.

II. $$u = \frac{d\,F + D\,M}{D\text{-}d} + S$$

u	Total unsharpness in mm
F	Projected focal spot size in mm
d	Part-Film Distance in inches (cms)
D	Target-Film Distance in inches (cms)
M	Motion of the part in mm
S	Screen blurring factor in mm

a. The distance factors may be expressed in inches or centimeters, provided that the same unit of measurement is used for both.

b. This formula includes all sources of radiographic unsharpness, except the following:

1. Vibration of the tube during the exposure.
2. Vibration of the film carrier.
3. Detail loss introduced by double emulsion films, when severe angulation is used in the radiographic projection.
4. Grain size in X-ray film emulsions.
5. Occasional detail losses introduced during processing.

C. EXAMPLES:

1. LATERAL LUMBAR SPINES

A Common Technique

50 Ma. Stationary Anode Focal Spot 4.2 mm

5 seconds Exposure Time	Motion	None
Target-Film Distance		36 inches
Part-Film Distance		6 inches
Screens	Par-Speed	.15 mm

$$u = \frac{6 \times 4.2}{30} + .15$$

$$u = .99 \text{ mm}$$

Careful immobilization will allow us to use:
20 Ma. (Rectified)

Stationary Anode Tube	Focal Spot	1.5 mm
12.5 Seconds Exposure Time	Motion	None
Target Film Distance		36 inches
Part-Film Distance		6 inches
Screens	Par-Speed	.15 mm

$$u = \frac{6 \times 1.5}{30} + .15$$

$$u = .45 \text{ mm}$$

II. GALL BLADDER

The following technique was at first considered ideal because of the "maximum Bucky Distance"; analysis proved that the reason for the persistent blurring was still "Focal Spot."

100 Ma. Stationary Anode Tube	Focal Spot	4.2 mm
2 Seconds Exposure Time	Motion	.05 mm
Target-Film Distance		40 inches
Part-Film Distance		3 inches
Screens	High Speed	.20 mm

$$u = \frac{3 \times 4.2 + 40 \times .05}{37} + .20$$

$$u = .594 \text{ mm}$$

A conversion was made as follows:
50 Ma. (Rectified)

Stationary Anode Tube	Focal Spot	2.1 mm
2 Seconds Exposure Time	Motion	.05 mm
Target-Film Distance		30 inches
Part-Film Distance		3 inches
Screens	High Speed	.20 mm

$$u = \frac{3 \times 2.1 + 30 \times .05}{27} + .20$$

$$u = .488 \text{ mm}$$

III. HEART

(Estimated Speed of Movement 5 mm/sec)
To show the fallacy of making "six foot heart pictures" on small equipment.
30 Ma. (Self Rectified)

Stationary Anode Tube	Focal Spot	2.1 mm
¼ Second Exposure Time	Motion	1.25 mm
Target-Film Distance		72 inches
Part-Film Distance		5 inches
Screens	Fast Speed	.20 mm

$$u = \frac{5 \times 2.1 + 72 \times 1.25}{67} + .20 \text{ mm}$$

$$u = 1.70 \text{ mm}$$

A good routine Technique is as follows:

200 Ma. Stationary Anode Tube	Focal Spot	4.2 mm
1/20 Second Exposure Time	Motion	.25 mm
Target-Film Distance		72 inches
Part-Film Distance		5 inches
Screens	Par-Speed	.15 mm

$$u = \frac{5 \times 4.2 + 72 \times .25}{67} + .15 \text{ mm}$$

$$u = .732 \text{ mm}$$

When Stationary Anode Tubes are used, the ever-present restriction of "limit Ma. per square mm of focal spot area" is imposed. When this restriction limits our technical possibilities, we make use of:

D. THE ROTATING ANODE TUBE

The rotating anode tube allows us to use currents approximately ten times greater than would be possible with a Stationary Anode tube of the same focal spot size.

If we made use of a Rotating Anode Tube in each of the three previous examples, our results could be as follows:

I. LATERAL LUMBAR SPINE

100 Ma. Rotating Anode Tube	Focal Spot	1 mm
2.5 Second Exposure Time	Motion	None
Target-Film Distance		36 inches
Part-Film Distance		6 inches
Screens	Par-Speed	.15 mm

$$u = \frac{1 \times 6}{30} + .15$$

$$u = .35 \text{ mm}$$

II. GALL BLADDER

150 Ma. Rotating Anode Tube	Focal Spot	1 mm
1 Second Exposure Time	Motion	.025 mm
Target-Film Distances		30 inches
Part-Film Distance		3 inches
Screens	Par-Speed	.15 mm

$$u = \frac{1 \times 3 + 30 \times .025}{27} + .15$$

$$u = .289 \text{ mm}$$

III. HEART RADIOGRAPHY

500 Ma. Rotating Anode Tube	Focal Spot	2 mm
1/60 Second Exposure Time	Motion	.083 mm
Target-Film Distance		72 inches
Part-Film Distance		5 inches
Screens	Par-Speed	.15 mm

$$u = \frac{5 \times 2 + 72 \times .083}{67} + .15$$

$$u = .388 \text{ mm}$$

The generous capacity of modern Rotating Anode Tubes makes practical the use of Slow Speed (fine grain) Intensifying Screens. Two examples of "Ultra Sharp Radiographic Detail" are as follows:

IV. SKULL RADIOGRAPHY

A Common Technique (For comparison)

50 Ma. Stationary Anode Tube	Focal Spot	4.2 mm
2 Second Exposure Time	Motion	None
Target-Film Distance		36 inches
Part-Film Distance (Sella Turcica to film)		4.5 inches
Screens	High Speed	.20 mm

$$u = \frac{4.5 \times 4.2}{31.5} + .20$$

$$u = .80 \text{ mm}$$

An Ultra-Sharp Technique:

100 Ma. Rotating Anode Tube	Focal Spot	1 mm
2 Second Exposure Time	Motion	None
Target-Film Distance		36 inches
Part-Film Distance		4.5 inches
Screens	Slow (Fine grain)	.06 mm

$$u = \frac{4.5 \times 1}{31.5} + .06$$

$$u = .20 \text{ mm}$$

V. CHEST RADIOGRAPHY

(Estimated Speed of Movement 1.5 mm/sec) — (For comparison).

100 Ma. Stationary Anode Tube	Focal Spot	4.2 mm
1/10 Second Exposure Time	Motion	.15 mm
Target-Film Distance		72 inches
Part-Film Distance		6 inches
Screens	Fast	.20 mm

$$u = \frac{6 \times 4.2 + 72 \times .15}{66} + .20$$

$$u = .746 \text{ mm}$$

Ultra-Sharp Chest Radiography

500 Ma. Rotating Anode Tube	Focal Spot	2 mm
1/20 Second Exposure Time	Motion	.075 mm
Target-Film Distance		72 inches

Part-Film Distance 6 inches
Screens Slow (Fine grain) .06 mm

$$u = \frac{6 \times 2 + 72 \times .075}{66} + .06 \text{ mm}$$

$$u = .324 \text{ mm}$$

E. *CONCLUSIONS:*

Detail (minimum of image unsharpness) is the most important quality in the radiograph.

Careful immobilization and the use of smaller focal spots is the logical improvement.

A *Rotating Anode Tube* and Slow (fine grain) Intensifying Screens (or better still "Non-Screen" techniques) for "Ultra-Sharp Radiographic Detail."

Section VI

EXPOSURE FACTORS

Generally speaking the density of any radiographic image depends upon the amount of radiation reaching the sensitized emulsion of the film. The amount of radiation in turn is influenced by the distance of the rays (anode) from the film, the M.A. used and kilovoltage used, the duration of the action (exposure time), the extent to which the rays are diminished in intensity in passing through the protective filter and the part being radiographed; and the intensity of the fluorescent light, when intensifying screens are used. All of these factors must be fully understood.

Radiographic Energy

Any change in the distance between the anode and the film (anode film distance) influences the effective intensity of the radiation which always varies *inversely* as the square of the distance and since X-rays conform to the laws of light they diverge when they are emitted from the anode, and cover an increasingly larger area with lessened intensity as they travel from their source.

Radiographic energy = voltage × current × time.

$$RE = \frac{V \times C \times T}{D^2} \qquad \frac{(\text{kilovoltage}) \times (\text{M.A.}) \times (\text{Seconds})}{\text{Distance}^2 \text{ (inches or centimeters)}}$$

The value of K.V.P. has direct influence not only upon the penetrating power of the rays, but also upon the contrast of the radiograph. Increasing the kilovoltage increases the penetrating power of the rays and generally speaking, diminishes radiographic contrast. Decreasing kilovoltage has the contrary effects.

An increase of 10 K.V.P. is equal to half the time.

Example 50 M.A.—60 K.V.P. at one second
or 50 M.A.—70 K.V.P. at one half second equals the same density.

For shorter exposure increase 10 K.V.P. and reduce time or M.A. in half. Other factors remain constant.

Relation Between Milliamperage and Distance

When radiographing children and nervous patients it is often necessary to employ high m.a. in order to obtain the advantages of very short exposure.

Rule: The milliamperage (m) required for a given exposure is directly proportional to the square of the anode film distance (d).

Example: Suppose that 50 M.A. (M_1) and an anode film distance of 36′ (D_1) have been employed and it is desired to increase the distance to 72″ (D_2) in order to obtain sharper detail, what M.A. would be required?

$M_1 : M_2 :: D^2_1 : D^2_2$
$50 : x :: 36^2 : 72^2$
$1296\ x = 259200$
$x = 200$ milliamperes

Example: Suppose that 100 milliamperes (M_1) and an anode film distance of 72″ (D_1) have been employed with a large focal spot X-ray tube and it is desired to change to a smaller focus tube designed to operate at considerably lower milliamperage. The milliampere factor selected is 20 (M_2), what distance (D_2) would be required?

$M_1 : M_2 :: D^2_1 : D^2_2$
$100 : 20 :: 72^2 : x^2$
$100\ x^2 = 103680$
$x = 32.2$ inches.

Example: Suppose that with a double focus rotating anode tube having 1 mm and 2 mm focal spots or 500 milliamperes (M_1) and an anode film distance of 72″ (D_1) have been employed for the 2 mm focal spot. It is desired to employ the 1 mm focal spot with a milliamperage factor of 175 M_2, what anode film distance (D_2) would be required?

$M_1 : M_2 :: D^2_1 : D^2_2$
$500 : 175 :: 72^2 : x^2$
$500\ x^2 = 907200$
$x = 42.6$ inches

Relation Between Milliamperage and Time

Rule: The milliamperage (M) required for a given exposure is inversely proportional to the time (T).

Example: Suppose that 30 milliamperes (M_1) and an exposure time of ½ second (T_1) have been employed and it is desired to decrease the exposure time to 1/20 sec. (T_2), what milliamperage would be required?

$M_1 : M_2 :: T_2 : T_1$
$30 : x :: 1/20 : ½$
$1/20x = 15$
$x = 300$ M.A.

$$\frac{x}{20} = \frac{15}{1}$$
$x = 15 \times 20$
$x = 300$

Example: Suppose that 30 M.A. (M_1) and an exposure time of 2 seconds (T_1) have been employed, and it is desired to increase the milliamperage to 60 (M_2) what exposure time (T_2) would be required?

$M_1 : M_2 :: T_2 : T_1$
$30 : 60 :: x : 2$
$60\ x = 60$
$x =$ one second

Relation Between Time and Distance

Rule: The exposure time (T) required for a given exposure is directly proportional to the square of the anode film distance (D).

Example: Suppose that an exposure time of 10 seconds (T_1) and an anode film distance of 30″ have been employed, and it is desired to decrease the anode film distance to 24″ (D_2), what exposure time T_2 would be required?

$T_1 : T_2 :: D^2_1 : D^2_2$
$10 : x :: 30^2 : 24^2$
$900x = 5760$
$x = 6.4$ seconds

Example of this problem: Would apply to radiography of the tempro-mandibula joint, where use of close focal film distance is desired.

Example: Suppose that an exposure time of two seconds (T_1) and an anode film distance of 72″ (D_1) have been employed, and it is desired to decrease the exposure time to ¼ second (T_2), what distance (D_2) would be required?

$T_1 : T_2 :: D^2_1 : D^2_2$
$2 : ¼ :: 72^2 : x^2$
$2x^2 = 1296$
$x = 25.5$ inches

Relation Between Milliamperage Time and Distance

Since the milliamperage (M) and the time (T) required for a given exposure are both directly proportional to the square of the anode film distance (D) the product of the two, milliampere seconds (m.a.s.) or (MT) is also directly proportional to the square of the anode film distance (D).

Example: Suppose that 60 (MAS), (MT_1) and an anode film distance of 36″ (D_1) have been employed and it is desired to increase the anode film distance to 72″ (D_2), what milliampere-seconds factor (MT_2) would be required?

$MT_1 : MT_2 :: D^2{}_1 : D^2{}_2$

$60 : x :: 36^2 : 72^2$

$1296x = 311040$

$x = 240$ milliampere-seconds

An easy method for calculating the change in milliampere-seconds (Ma.S.) is based on the principle that the *squares* of numbers bear constant mathematical relation to each other. In the above example, the square of the number representing the longer anode-film distance, 72^2 (5184), is 4 times the square of the number representing the shorter anode-film distance, 36^2 (1296). Therefore, if the number representing the proper Ma.S. factor at the 36″ anode-film distance, 60, is multiplied by 4, the proper milliamperage-time for the 72″ distance will be found to be 240 Ma.S. Conversely, 36^2 (1296) is one-fourth (.25) of 72^2 (5184); so, if the number representing the proper Ma.S. factor at 72″, 240, is multiplied by .25, the proper milliamperage-time for the 36″ distance will be found to be 60 Ma.S.

The interrelation of all anode-film distances may be similarly expressed by means of a conversion factor. Any change in milliamperage-seconds necessitated because of a change in the anode-film distance may then be calculated by multiplying by the proper factor, the initial milliamperage-seconds value. The chart below lists the factors that apply for anode-film distances commonly employed in radiography. To use it, the initial anode-distances commonly employed in radiography. To use it, the initial anode-film distance is located in the left-hand vertical column and the desired distance is located in the horizontal column at the bottom of the chart. The required conversion factor will be found in the square common to both columns.

INITIAL ANODE-FILM DISTANCE	FACTORS							
20 in.	1.00	1.56	2.25	3.22	4.00	5.76	9.00	12.96
25 in.	.64	1.00	1.44	2.07	2.56	3.68	5.76	8.29
30 in.	.44	.69	1.00	1.44	1.77	2.56	4.00	5.76
36 in.	.31	.48	.69	1.00	1.23	1.77	2.77	4.00
40 in.	.25	.39	.56	.81	1.00	1.44	2.25	3.24
48 in.	.17	.27	.39	.59	.69	1.00	1.56	2.25
60 in.	.11	.17	.25	.36	.44	.64	1.00	1.44
72 in.	.08	.12	.17	.25	.31	.44	.69	1.00
DESIRED ANODE-FILM DISTANCE	20 in.	25 in.	30 in.	36 in.	40 in.	48 in.	60 in.	72 in.

PERCENTAGE OF MAGNIFIED RADIOGRAPHIC DISTORTION AT VARYING OBJECT-FILM AND TARGET-FILM DISTANCES

Object-Film Distance:	Target-Film Distance: 2 Ft.	3 Ft.	4 Ft.	5 Ft.	6 Ft.	7 Ft.	8 Ft.	9 Ft.	10 Ft.
1 inch	4.34	2.86	2.13	1.69	1.41	1.20	1.05	.93	.84
2 inches	9.05	5.88	4.35	3.45	2.85	2.44	2.13	1.89	1.69
3 inches	14.29	9.05	6.67	5.26	4.35	3.70	3.24	2.85	2.56
4 inches	20.00	12.50	9.05	7.14	5.88	5.00	4.35	3.85	3.45
5 inches	26.31	16.13	11.64	9.09	7.46	6.32	5.49	4.85	4.35
6 inches	33.33	20.00	14.29	11.11	9.09	7.69	6.67	5.88	5.26
7 inches	41.18	24.14	17.07	13.27	10.77	9.11	7.86	6.93	6.19
8 inches	50.00	28.57	20.00	15.38	12.49	10.53	9.09	8.00	7.14

APPROXIMATE CHANGE IN KVP PER CM. FROM A GIVEN BASIC TECHNIQUE AT VARIOUS KV RANGES, USING PAR-SPEED SCREENS

Kvp.:	Change per centimeter:
30-40	1 -1½ Kvp.
40-55	1½-2 Kvp.
55-70	2 -2½ Kvp.
70-85	3 Kvp.

CASSETTE LOCATION FOR VARYING ANGLES OF TUBE TILT

(Inches from directly beneath tube to center of cassette)

Angle of tilt	Height of tube 25″	28″	30″	36″
3°	1¼″	1½″	1⅝″	1⅞″
6°	2⅝″	3″	3⅛″	3¾″
9°	4″	4½″	4¾″	5¾″
12°	5⅜″	6″	6⅜″	7⅝″
15°	6¾″	7½″	8″	9⅝″
18°	8⅛″	9⅛″	9¾″	11¾″
21°	9⅝″	10¾″	11½″	13⅞″
24°	11⅛″	12½″	13⅜″	16″

STEREO TUBE SHIFT (INS.)

Anode Film Dist	Viewing Distance 25″	27″	29″	31″
25″	2½″	2¼″	2⅛″	2″
28″	2¾″	2⅝″	2⅜″	2¼″
30″	3″	2¾″	2⅝″	2⅜″
36″	3⅝″	3⅜″	3⅛″	2⅞″
40″	4″	3¾″	3½″	3¼″
48″	4¾″	4½″	4⅛″	3⅞″
60″	6″	5½″	5¼″	4⅞″
72″	7¼″	6¾″	6¼″	5¾″

TABLE FOR CONVERSION OF MA-SECONDS INTO FRACTIONS OF A SECOND AT VARIOUS MILLIAMPERAGES

Milliampere-seconds:

Ma:	4	6	8	10	12	14	16	18	20	24
50	1/12	1/8	1/6	1/5	1/4	1/3		....	2/5	1/2
100	1/25	1/17	1/12	1/10	1/8	1/7	1/6	....	1/5	1/4
150	....	1/25	1/20	1/15	1/12	....	1/10	1/8	1/7	1/6
200	....	....	1/25	1/20	....	1/15	1/12	....	1/10	....
250	....	....	....	1/25	1/20	....	1/15	....	1/12	1/10
300	....	....	....	....	1/25	....	1/20	....	1/15	1/12

Ma:	26	28	30	32	34	36	40	42	50
50	....	....	3/5	....	....	3/4	4/5	....	1
100	....	....	....	1/3	....	....	2/5	....	1/2
150	....	....	1/5	....	1/4	....	....	....	1/3
200	1/8	1/7	....	....	1/6	....	1/5	....	1/4
250	....	....	....	1/8	....	1/7	....	1/6	1/5
300	....	....	1/10	....	....	1/8	....	1/7	1/6

Section VII

THE TECHNIC CHARTS

Formulating a technic chart for any type of equipment that is to be used in the X-ray department, employing the tissue thickness measurement of the part to be radiographed, is not a very hard procedure. Tissue thickness measurement is one of the most satisfactory means of determining the kilovoltage to be used.

Described in this chapter are two methods for formulating technic charts. The first type is designed for the use of different kilovoltage and milliampere-seconds scales as the variable factors for the so-called various groups, arranged according to parts of similar radio-opacity. The second type employes only five kilovoltage scales for the entire chart and the milliampere-seconds as the variable factor. The five kilovoltage scales are for bucky, no bucky, lateral lumbar, lateral thoracic, and chest radiography.

To compensate for tissue differences in the small, medium, and large patients, classifications of "A", "B", and "C" are used. "A" representing the thin and emaciated patient, "B" representing the normal or medium sized patient, and "C" representing the large or muscular patient. For "A", "B", and "C" classifications milliampere-second values are given; for example, in the radiography of the three types of lumbar spines each measuring the same centimeter thickness, "A" would require less milliampere-seconds and "C" would require more milliampere-seconds than the "B" type patient. It is apparent that if the same peak kilovoltage and the same milliampere-seconds were given all three patients, the "A" type patient's radiograph would be over-exposed while the "C" type patient's would be under-exposed. Milliampere-seconds are used as the variable factor in both types of charts to compensate for these conditions; and the kilovoltage scales are varied for different parts of the body in the technic chart type one.

Technic Chart Type One

The different groups into which the parts to be radiographed are divided are:

1. Group One.
    a. Antero-posterior, postero-anterior, lateral, mento-vertex, and vertex-mento skull.

- b. Antero-posterior and lateral sella turcica.
- c. Lateral and postero-anterior (bucky) maxillary, frontal, sphenoid, and ethmoid sinuses.
- d. Antero-posterior, postero-anterior, and oblique petrous apices.
- e. Postero-anterior optic foramina.

2. Group Two.
    - a. Lateral and postero-anterior maxillary, frontal, sphenoid, and ethmoid sinuses without the bucky.
    - b. Postero-anterior, lateral, and oblique mandible.
    - c. Antero-posterior, lateral, and oblique temporomandibular joints.
    - d. Lateral and antero-posterior mastoid process.
3. Group Three.
    - a. Antero-posterior and oblique atlas and axis.
    - b. Antero-posterior and oblique cervical spine.
    - c. Antero-posterior and lateral shoulder.
    - d. Antero-posterior and lateral scapulae.
    - e. Antero-posterior and infero-superior clavicle.
    - f. Postero-anterior and oblique sterno-clavicular joint.
    - g. Oblique sternum.
    - h. Antero-posterior cervical-dorsal spine.
    - i. Antero-posterior and oblique dorsal spine.
4. Group Four.
    - a. Lateral cervical-dorsal spine with filter.
    - b. Lateral dorsal spine.
5. Group Five.
    - a. Antero-posterior and oblique lumbar spine.
    - b. Antero-posterior and oblique sacroiliac joints.
    - c. Antero-posterior sacrum.
    - d. Antero-posterior coccyx.
    - e. Antero-posterior pelvimetry.
    - f. Lateral hip and antero-posterior pelvis.
    - g. Antero-posterior and lateral femur.
6. Group Six.
    - a. Lateral lumbar spine.
    - b. Lateral sacrum.
    - c. Lateral coccyx.
    - d. Lateral pelvimetry.
    - e. Lateral lumbo-dorsal spine.

7. Group Seven.
    - a. Antero-posterior abdomen.
    - b. Ureters.
    - c. Urinary bladder.
    - d. Urethra.
    - e. Kidneys.
    - f. Gall bladder.
    - g. Gastrointestinal tract.
    - h. Serialograph.
    - i. Barium Enema.
8. Group Eight.
    - a. Lateral placenta with Barium filter.
    - b. Soft tissue radiography.
9. Group Nine.
    - a. Antero-posterior, postero-anterior, lateral, and oblique chest.
    - b. Lateral and oblique oesophagus.
    - c. Lateral pharynx.
    - d. Lateral larynx.
    - e. Lateral and oblique trachea.
    - f. Lateral hyoid bone.
    - g. Lateral sternum.
    - h. Lateral sterno-clavicular joint.
    - i. Lateral cervical spine.
10. Group Ten.
    - a. Extremities taken with screens or no-screens.
11. Group Eleven.
    - a. Infant's technique for the above listed groups.
12. Group Twelve.
    - a. Children's, from 2 to 10 years, technique for the above listed groups.

Machine Capacity

Take for example a four valve tube, full wave rectified machine with the following capacity and tube rating:

Capacity.

35 to 90 peak kilovolts
20 milliamperes to 200 milliamperes
Exposure scale from 1/20 of a second to 20 seconds

Tube Rating.

20 milliamperes	90 peak kilovolts	15 seconds continuously
30 milliamperes	90 peak kilovolts	10 seconds continuously
50 milliamperes	90 peak kilovolts	5 seconds continuously
100 milliamperes	90 peak kilovolts	2 seconds continuously
200 milliamperes	90 peak kilovolts	1/10 second

Focal Spots.

20, 30, and 50 milliamperes on the small focus.
100 and 200 milliamperes on the large focus.

The above represents the maximum capacity of our tube. With these ratings in mind we start our chart.

Select an average size individual; for example, 150 pounds, 5 feet, 10 inches tall, the weight evenly distributed. Start with the work that is to be done with the bucky. Since the best detail and contrast are desired, use the smallest focal spot possible for the type of work being done and a medium exposure time well within the tube's rating limit.

The lateral skull of the first group gives us an excellent starting point. Measure the subject in the lateral skull position. On the average this measurement will be found to be 15 centimeters. Multiply the centimeter thickness obtained by 2 and add the figure 27 to the product. In this manner a peak kilovoltage of 57 is calculated. The focal-film distance used depends upon the type of bucky employed. We will use a 36 inch focal-film distance in this case, and a cone which will restrict our radiation to an area not much larger than the part being radiographed. The milliampere-seconds used depend upon the individual's choice. The technical factors we will use, then, are:

Focal-Film Distance
36 inches
Centimeter Thickness......15
Peak Kilovoltage................57
Milliampere-Seconds
A................. 75
B.................105
C.................120

Place the subject in the lateral skull position and make an exposure with the above technical factors. Develop the film according to the standard time-temperature development and view the film on the viewing box on which the films are to be read. If it lacks the necessary detail or contrast, change any of the necessary four prime factors in proportion. Expose another film and continue the above process until the proper radiograph is obtained. Note the change required to produce the diagnostic film and this will hold true for the entire group. Using the 15 centimeters and the required, say 57 peak kilovolts, kilovoltage as a basis, add two peak kilovolts for each centimeter thickness. For example:

Centimeter thickness:	13	14	15	16	17
Peak kilovoltage:	53	55	57	59	61

This procedure is followed throughout the entire chart for each group. Group Six will necessitate more milliampere-seconds than any other group, approximately 600.

To adopt any technic chart to your machine simply make a radiograph of the lateral skull, using the technical factors given in the chart. Process the film under standard conditions, determine the necessary prime factor corrections and apply these corrections to the other parts included in the groups of similar opacity. This same routine will hold true for all groups. Select a region for study from each of the other groups and apply the same routine as described above.

For the children from 2 to 10 years use 50% less milliamperage and the same kilovoltage used for the average adult technique; for infants use the same kilovoltage as suggested for average adult technique and reduce the milliampere-seconds 60%.

In some cases a fast technique will have to be used on uncooperative patients. The exposure factors can be worked out by trial and error methods, but it is recommended that the time-milliamperage formula be used.

Time-Milliamperage Formula.

The milliamperage required for a given exposure is inversely proportional to the time.

Example: To change the time of a 50 milliamperes exposure from 2 seconds to ½ second, what new milliamperage must be used?

$$M_1 : M_2 :: T_2 : T_1$$
$$50 : X :: \tfrac{1}{2} : 2$$
$$\tfrac{1}{2}X = 100$$
$$X = 200 \text{ milliamperes}$$

Next take the no bucky work, arranging a technique for the extremities. Use a 36 inch anode-film distance, 10 milliampere-seconds, and par-speed screens as a basis. The kilovoltage is obtained by measuring the part in centimeters, multiplying by 2, and adding the figure 27.

Example:

Milliampere-seconds	Distance	Screen
10	36 inches	par-speed

Centimeters	1	2	3	4	5	6	7	8	9	10
Kilovoltage	29	31	33	35	37	39	41	43	45	47

In changing from screen radiography to no screen radiography the ratio of the milliampere-seconds is 1 to 5.

The Chest. Chest radiography is very exact and the kilovoltage and milliamperage settings must be accurate. It is a good idea to check the timer for accuracy by the spinning top method before making the chest technic chart, since fractional second exposures are to be used.

The following milliampere-seconds will be known as balance contrast settings:

A. from 15 to 27 centimeters .... 10 milliampere-seconds

B. from 28 to 33 centimeters .... 20 milliampere-seconds

It is advisable to use a 72 inch anode-film distance for chest radiography and no bucky except when there is dense pathology; then the bucky and a 48 inch anode-film distance should be used.

The chest chart will be similar to the following:

Milliampere-Seconds	Distance
10	72 inches

Centimeters	15	16	17	18	19	20	21	22	23	24	25	26	27
Peak Kilovolts	50	50	50	52	54	56	58	60	62	64	66	68	70

In children it will be found that the chest is a little more dense than the 14 or 15 centimeter adult chest; so 10 milliampere-seconds are used throughout the children's chest range, that being from about 10 to 16 centimeters.

The infant's chest, 1 month to 18 months, is more dense than the chests of children from 2 to 10 years; so this is compensated by using more KV, M.A. or decreasing the distance.

Special Chest Techniques.

Oblique adult chest—
add 8 kilovolts to the postero-anterior measurement
Lateral adult chest—
add 15 kilovolts to the postero-anterior measurement
Oblique children's chest—
add 8 kilovolts to the postero-anterior measurement
Lateral children's chest—
add 12 kilovolts to the postero-anterior measurement
Oblique infant's chest—
add 6 kilovolts to the postero-anterior measurement
Lateral infant's chest—
add 10 kilovolts to the postero-anterior measurement

The 10 Milliampere Portable Unit

The peak kilovoltage is obtained by multiplying the centimeter thickness by 2 and adding the figure 27.

Part	*Milliampere-Seconds*	*Distance*	*Lysholm Grid*
A. P. Chest	2	30 in.	no
A. P. Skull	30	30 in.	yes
Lat. Skull	30	30 in.	yes
Lat. Mastoid	10	30 in.	no
P. A. Sinuses	10	30 in.	no
Abdomen	30	30 in.	yes
A. P. Hip	50	30 in.	yes
Lat. Hip	200	25 in.	yes
Pelvis	50	30 in.	yes
Extremities on screen	10	30 in.	no
Extremities on no screen	50	30 in.	no

Basic technique charts can be obtained from Westinghouse X-ray Company, General Electric X-ray Company, Kelley-Koett X-ray Company and Picker X-ray Company free on request.

Technic Chart Type Two

The type two chart employs only five kilovoltage scales and uses the milliampere-seconds as the variable factor.

The kilovoltage for this type chart is computed in the same manner as used for the type one technic chart. The basic milliampere-seconds used are 10, 100, and 300. A 50% reduction of the milliampere-seconds factor for children's technique is made and a 60% reduction for infant's.

To adopt this type of chart to any machine make a radiograph of parts employing the five different kilovoltage scales. Process the films by standard time-temperature development and note the prime factor changes necessary to produce the type of films the radiologist requires. These changes will hold true throughout the entire chart for the respective kilovoltage scales.

Note. The kilovoltage in Chart 2 has been adjusted to give maximum detail and contrast for one particular machine. The milliamperage and time on this chart are stated in milliampere-seconds values, the milliampere-seconds being made up of the product of the milliamperes used and the time in seconds. For example, 100 milliampere-seconds can be obtained by using 50 milliamperes for 2 seconds, 10 milliamperes for 10 seconds, or 100 milliamperes for 1 second.

CHART 2

Section 1.

Region	*Position*	*Milliampere-Seconds*	*Kilovoltage Scale*	*Bucky*	*Distance*
Skull	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.
Skull	Lat.	A .... 75 B .... 100 C 125	1	yes	30 in.
Skull	Mento-Vertex	A .... 75 B .... 100 C 125	1	yes	30 in.
Sinuses	Lat.	A .... 15 B .... 25 C 30	2	no	27 in.
Sphenoid	P. A.	A .... 75 B .... 100 C 125	2	no	27 in.
Frontal	P. A.	A .... 75 B .... 100 C 125	2	no	27 in.
Maxillary	P. A.	A .... 75 B .... 100 C 125	2	no	27 in.
Mastoid	Lat.	A .... 75 B .... 100 C 125	2	no	27 in.
Mastoid Tips	A. P.	A .... 75 B .... 100 C 125	2	no	27 in.
Mandible	P. A.	A .... 75 B .... 100 C 125	1	yes	30 in.
Mandible	Lat. or Oblique	A .... 40 B .... 60 C 70	2	no	27 in.

PEAK KILOVOLTAGE SCALE 1		PEAK KILOVOLTAGE SCALE 2		PEAK KILOVOLTAGE SCALE 3		
Centimeters	*Peak Kilovolts*	*Centimeters*	*Peak Kilovolts*	*Centimeters*	*Lumbar kilovoltage*	*Dorsal kilovoltage*
2	35	8	30	20	48	60
3	36	9	32	21	50	62
4	37	10	34	22	52	64
5	38	11	36	23	54	66
6	39	12	38	24	56	68
7	40	13	40	25	58	70
8	42	14	42	26	60	72
9	44	15	44	27	62	74
10	46	16	46	28	64	76
11	48	17	48	29	66	78
12	50	18	50	30	68	80
13	52	19	52	31	74	82
14	54	20	54	32	76	
15	56	21	56	33	78	
16	58	22	58	34	80	
17	60	23	60			
18	62	24	62			
19	64					
20	66					

Section 2.

Region	*Position*	*Milliampere-Seconds*	*Kilovoltage Scale*	*Bucky*	*Distance*
Atlas Axis	P. A.	A .... 75 B .... 100 C 125	1	yes	30 in.
Cervical Spine	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.
Cervical Spine	Lat.	A .... 75 B .... 100 C 125	2	no	72 in.
Shoulder	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.
Dorsal Spine	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.
Dorsal Spine	Lat.	A .... 75 B .... 100 C 125	4	yes	30 in.
Lumbar Spine	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.
Lumbar Spine	Lat.	A .... 250 B .... 300 C 350	3	yes	30 in.
Spot Film 5th Lumbar & Coccyx	Lat.	A .... 350 B .... 400 C 450	3	yes	30 in.
Pelvis	A. P.	A .... 75 B .... 100 C 125	1	yes	30 in.

Section 3.

Region	*Position*	*Milliampere-Seconds*	*Distance*	*Peak Kilovoltage Scale*	*Bucky*
Abdomen	A. P.	A.......... 75 B..........100 C..........125	30 in.	1	yes
Gall Bladder	Lat.	A.......... 75 B..........100 C..........125	30 in.	1	yes
Pelvimetry	A. P.	A..........100 B..........150 C..........175	30 in.	1	yes
Bladder	A. P.	A.......... 75 B..........100 C..........125	30 in.	1	yes
Kidneys	A. P.	A.......... 75 B..........100 C..........125	30 in.	1	yes
G. I. Series	A. P. P. A.	A.......... 40 B.......... 50 C.......... 60	30 in.	1	yes
Serialograph	A. P. P. A.	A.......... 40 B.......... 50 C.......... 60	30 in.	1	yes
Oesophagus Spot Film	oblique	A.......... 15 B.......... 20 C.......... 30	30 in.	A..........70 B..........80 C..........85	no

Section 4.

Region	*Position*	*Milliampere-Seconds*	*Distance*	*Kilovoltage Scale*	*Bucky*
Chest	P. A.	A..........10 B..........12 C..........15	72 in.	5	no
Chest	oblique	A..........15 B..........20 C..........25	72 in.	5 (add 10 peak kilovolts to P. A. measurements)	no
Chest	Lat.	A..........15 B..........20 C..........25	65 in.	5 (add 15 peak kilovolts to P. A. measurements)	no
Oesophagus	oblique	A..........15 B..........20 C..........25	65 in.	5 (add 10 peak kilovolts to P. A. measurements)	no

Section 5.

ADULT EXTREMITIES

Screen

Milliampere-Seconds	Distance	Kilovoltage Scale	Bucky
10	30 in.	1	no

No Screen

Milliampere-Seconds	Distance	Kilovoltage Scale	Bucky
50	30 in.	1	no

PEAK KILOVOLTAGE SCALE 5

Centimeters	*Peak Kilovolts*	*Centimeters*	*Peak Kilovolts*
12	50	21	68
13	52	22	70
14	54	23	72
15	56	24	74
16	58	25	76
17	60	26	78
18	62	27	80
19	64	28	82
20	66	29	84

Note: For infant's and children's chest see Chest, page —, under Technic Chart Type One.

Optimum Kilovoltage Technic

In the early days of radiography when gas tubes were the only type available, it was the common practice to have a considerable number of such tubes at hand, each one selected for its ability to record a particular part of the body to best advantage. Kilovoltage was measured by the length of the spark between points, and it was not unusual to employ 6″ to 9″ spark-gaps representing 85 to 125 kilovolts.

In general, the development of apparatus and X-ray sensitive materials during the past decade was directed toward the utilization of lower kilovoltages to produce higher contrast in the radiographs, with the feeling that this was the best possible means of accentuating detail. When a radiographic image is recorded with sharpness, contrast can be reduced appreciably without loss in the perception of detail.

When it becomes possible to differentiate between tones in an image, radiographic contrast exists, contrast which is manifested by many tones or densities and the transition from one tone to another is gradual and small, is called *long-scale contrast.* When the transition from one tone to another is abrupt and the number of tones is small, *short-scale contrast* exists in the image.

The higher kilovoltages will produce the very desirable long-scale contrast while the lower kilovoltages will produce short-scale contrast.

The function of the kilovoltage is to provide an X-ray wave-length that in a given projection, will adequately penetrate a specific body part irrespective of its size. Also, that it will provide a satisfactory scale of contrast. The kilovoltage applied should be the minimum necessary to attain its objective when using a practical length of exposure.

When such a kilovoltage has been established as optimum for a given projection, it should be considered a constant and never changed. Any change in density required can then be provided by the Ma.S. factor. This procedure greatly simplifies the exposure technic.

For average thicknesses, a basic Ma.S. value may be established. When thicknesses are less or greater than the average, then the extreme exposure latitude of the film provided by an optimum kilovoltage makes possible halving or doubling the Ma.S. value to secure the density value usually associated with the average sized part. *In other words, radiographic density is altered by Ma.S. and the kilovoltage influences X-ray penetration and radiographic contrast.*

Necessary to the operation of this technic is time-temperature processing. By considering this type of processing as a constant, any over or underexposure can be attributable to incorrect application of the Ma.S. factor.

The optimum kilovoltage technique does not require actual measurement of the body part. With some experience, the technician learns to estimate the thickness and is able to classify the part as small, average or large. Since the average classification predominates, he may successfully place about 90 per cent of all patients in this category. The basic constants of kilovoltage and milliampere-seconds are so few in number that they are easily memorized.

Tubes

Damage to tubes is largely caused by milliamperage and not kilovoltage. Damage is related to the heat developed per unit area of focal spot and the rate at which it is applied. Most damage to tubes is caused by overloaded focal spots wherein melting and cracking of the bombarded area results; a single over-capacity exposure is sufficient to irreparably damage a tube. Such damage cannot be attributed to general overheating or thermal overload because the quantity of copper in the anode of most tubes usually is adequate to dissipate the heat generated under normal working conditions. The increase in roentgenographic efficiency produced by the use of increased kilovoltage is obtained with a proportionately smaller amount of heat because of the use of a lower milliamperage. When the tube is operated below its rated capacity, damage to the focal spot is relatively nil even though high kilovoltage is employed.

The normal human adult conforms to a general dimensional standard of body part thicknesses. In all projections, measurement is made along the path traversed by the central ray through the part. Since the thickness of any body part is not an index of its physiological or pathological state or its X-ray absorptive qualities, it cannot be employed as an index of the radiographic density to appear on an X-ray film. Every body part along a specified dimension consists of a proportionate amount of bone to flesh. Irrespective of the thickness, this proportionate relationship is fairly consistent. For this reason, the most favorable or optimum kilovoltage to adequately penetrate the part irrespective of thickness is employed.

There are three classes of radiography: (1) exposures made without screens; (2) screen exposures; and, (3) screen and grid exposures. Let us cite examples of each class.

The average thickness range of the hand for a P-A projection is 3-5 centimeters. An optimum kilovoltage is 50 when employing screen-sensitive film without screens. Employing a cone, the basic Ma.S. value is approximately 45 at a focus-film distance of 30". This value usually may be reduced if the efficiency of the apparatus requires it. About 95% of all adult cases may be given this exposure. If the hand is less than 3 cm. in thickness, the Ma.S. value is halved; if greater than 5 cm., the Ma.S. is doubled.

Let us consider an anterior posterior view of the shoulder when using average speed screens. An optimum kilovoltage of 60 when using a cone and a 30" distance will require a basic Ma.S. of approximately 15 for a thickness range of 12-16 cms. If the thickness is less than 12 cm., use 7.5 Ma.S.; if greater use 30 Ma.S.

The lateral view of the skull requires the use of a grid, medium speed screens and a cone. An optimum kilovoltage of 85 at a 30" focus-film distance is required for a thickness range of 13-17 cms.; the basic Ma.S. is approximately 15.

If Ma.S. is employed to regulate radiographic density and the KvP., penetration and contrast scale, changes for error are reduced to a minimum when time-temperature processing is used. Exceptional cases, of course, are often encountered. Patients with poorly nourished or atrophied parts may require but ¼ the Ma.S. listed.

There is one important consideration that must be made. Use every accessory possible to reduce the amount of secondary radiation generated. Cones, grids, and short exposures help to do this. Also, to secure balanced densities on the radiograph always align the long axis of the tube with the long axis of the part and direct the cathode portion of the beam toward the area of greatest tissue density.

OPTIMUM KILOVOLTAGE TECHNIC DIRECTIONS

TECHNIC DIRECTIONS

Technic Chart is based upon the use of 30 Ma. *self-rectified* apparatus. When employed on full-wave restified equipment, reduce basic Ma.S. values to conform to the added efficiency of the latter equipment as to radiographic density.

DO NOT CHANGE Kv.P. values.

MA.S.—

HALVE when thickness is LESS than average.

BASIC when thickness is AVERAGE.

DOUBLE when thickness is GREATER than average.

QUADRUPLE if radiographic density is insufficient for AP pelvis or AP lumbar spine.

Regulate radiographic density with Ma.S. not Kv.P.

ALWAYS ALIGN LONG AXIS OF TUBE WITH THAT OF PART AND DIRECT CATHODE PORTION OF X-RAY BEAM TOWARD AREA OF GREATEST TISSUE DENSITY.

Use MEDIUM-SPEED SCREENS and CONE or aperture diaphragms.

Use TIME-TEMPERATURE processing.

For chests, note special PA technical factors.

Distance: When distance is changed, adjust Ma.S. values.

Filtration: 1 mm. aluminum.

SYMBOLS

F—Plain Film	S—Screens	SG—Sreens and Grid

(Courtesy, Arthur W. Fuchs, Medical Technical Service
Eastman Kodak Company, Rochester 4, N. Y.)

REGION		AVERAGE THICKNESS (ADULT) CMS.				BASIC MA.S.	OPTIMUM KV.P.	DIST-ANCE
		AP	PA	LAT.				
THUMB - FINGER		1.5 - 4				45 F	50	30″
HAND		3 - 5						
				7-10		120 F		
WRIST				5-8				
		3 - 6				45 F		
FOREARM		6 - 9				75 F	60	
				7-10		105 F		
ELBOW		6-9				120 F		
				7-10				
ARM		7-10				5 S		
				7-10		3.75 S		
SHOULDER CLAVICLE		12-16				15 S		
			13-17					
FOOT		6 - 9				52.5 F		
				6-9		90 F		
ANKLE				6-9			65	
		7-10				105 F		
LEG		9-12				5 S	60	
				8-11		3.75 S		
KNEE		10 - 14				5 S	65	
				9-13		3.75 S		
THIGH		14-17				30 SG	75	
				13-16		22.5 SG		
HIP		17-21				60 SG		
CERVICAL VERTEBRAE	C1-7			10-13		15 S	85	60″
	C1-3	12-15				60 SG	65	30″
	C4-7	11-14				45 SG		
THORACIC VERTEBRAE		20-24				60 SG	75	
				28-32			85	
LUMBAR VERTEBRAE				27-32		150 SG		
		18-22				90 SG	70	
PELVIS		20-23						
GALL - BLADDER			20-24					
G-I. TRACT		18-22				25 SG	85	
SKULL			18-21			30 SG		
				13-17		15 SG		
		16-23				37.5 SG		
					INF.-SUP. 20-25	75 SG		
PARS PETROSA (STENVERS)					POST. LAT. 15-19	22.5 S	70	
SINUSES	ALL			13-17		12 S	65	30″
	FRONT.		18-21			22.5 S	75	
	MAX.		18-22			45 S		
FACIAL BONES			18-22			30 S		
MANDIBLE				9-12		7.5 S	70	
Mastoid, Temp-Mand. Jt.				14-17		15 S		
CHEST	SMALL		- 19			1.875 S	80	60″
	AVERAGE		20-25			3.75 S		
	LARGE		26-29			7.5 S		
	HUGE		30 -			15 S		
		20-25				7.5 S		
			OBL. 24-30	27-32		30 S	85	
						18 S		

DUKE HOSPITAL

RADIOGRAPHIC GUIDE

DURHAM, N.C.

L = Large Cone
C = Cylinder
M = Medium Cone
R = Rectangular
5 Min. Developing

Region	Position	Cone	M.A.	Sec.	Dist.	Bucky
Skull	Lateral	L	100	1	36	Yes
Skull	P.A. A.P.	L	100	1	36	Yes
Skull	Petrous	L	100	1	36	Yes
Skull	Mento-Vertex	L	100	1	36	Yes
Mandible	P.A.	C	100	1	30	Yes
Styloid	A.P. Oblique	C	100	1/2	30	Yes

C.M.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
K.V.	40	42	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70

Sinuses	Lateral	C	100	1/2	27	No
Sinuses	P.A. Frontals	C	100	1/2	23	No
Sinuses	P.A. Maxillary	C	100	1/2	27	No
Sinuses	P.A. Sphenoid	C	100	1/2	27	No
Sinuses	Lat. Bucky	C	100	1 1/2	27	Yes
Sinuses	P.A. Bucky	C	100	1 1/2	27	Yes

C.M.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
K.V.	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62

Mandible	Lateral	C	100	1/2	27	No
Styloid	Lateral	C	100	1/2	27	No
Optic	P.A.	C	100	1	27	Yes
Maxilla	Oblique Lat.	C	100	1/2	27	No
Mastoid	Lateral	C	100	1/2	27	No
Mastoid	Tips	C	100	1/2	27	No

C.M.	8	9	10	11	12	13	14	15	16	17	18
K.V.	36	38	40	42	44	46	48	50	52	54	56

Shoulder	A.P.	M	100	1	36	Yes
Scapula	A.P.	M	100	1	36	Yes
Scapula	Lateral	M	100	1	36	Yes

C.M.	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
K.V.	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70

Cervical	A.P.	R	100	1	36	Yes
Dorsal	A.P.	R	100	1	36	Yes
Lumbar	A.P.	R	100	1	36	Yes
Lumbar	Oblique	R	100	1	36	Yes
Pelvis	A.P.	L	100	1	36	Yes
Pregnancy	A.P.	L	100	1	36	Yes
Gall Bladder	P.A.	M	100	1/2	36	Yes
G.U. Tract	A.P.	L	100	1/2	36	Yes
Colon	A.P. P.A.	L	100	1	36	Ye

C.M.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
K.V.	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74

Stomach	P.A.	L	100	1/2	30	Yes
Stomach	Oblique	L	100	1/2	30	Yes
Stomach	Lateral	L	150	1/2	30	Yes

C.M.	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
K.V.	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80

SPECIAL LATERAL EXPOSURE TECHNIC

Region	Position	Cone	M.A.	Sec.	Dist.	Bucky
Cervical	Lateral	M	100	1/10	72	No
Cervical	Oblique	M	100	1/10	72	No
Hyoid	Lateral	M	100	1/20	72	No

C.M.	8	9	10	11	12	13	14	15	16	17	18	19
K.V.	66	68	70	72	74	76	78	80	82			

Lumbar	Lateral	R	100	2	36	Yes
Sacrum	Lateral	R	100	3	36	Yes
Pelvimetry	Lateral	L	100	2	30	Yes

C.M.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
K.V.	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88

Dorsal	Lateral	R	50	5	36	Yes
Sternoclav. art.	P.A.	M	50	5	36	Yes
Sternum	P.A.	M	50	5	36	Yes
Sternum	Lateral	M	100	1/10	72	No

C.M.	21	22	23	24	25	26	27	28	29	30	31	32	33
K.V.	48	50	52	54	56	58	60	62	64	66	68	70	72

Chest	P.A.	M	100	1/20	72	No
Chest	Oblique	M	100	1/20	72	No
Chest	Lateral	M	100	1/10	72	No

C.M.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
K.V.	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76

EXTREMITIES

Extremities	Adult-All	L	100	1/10	36	Screen
Extremities	Adult-All	L	100	1/4	36	No Screen
Extremities	Adult-All Bucky	L	100	1/4	36	Yes
Extremities	Soft Tissue	L	50	1/10	36	No

C.M.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
K.V.	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72

Note: CHILDREN — Reduce M.A.S. 50% except chest. For chest add 3 C.M. to measured thickness.
INFANT — Reduce M.A.S. 60% except chest. For chest use special chest exposure.

SPECIAL TECHNIQUES

PLACENTA

Barium plastic filter
100 MA - 36 "Dist. - 2 Sec.

Small	Med	Large
55 KV	60 KV	65 KV

CHEST - 2 YR - 10YR

P.A. 52 KV - 100 MA - 1/20 Sec. 72" Dist.
Oblique - 58 KV - 100 MA - 1/20 Sec.
Lat. - 64 KV - 100 MA - 1/20 Sec.

INFANT CHEST

200 MA - 72" - 1/20 Sec.
C.M. - 8 - 9 - 10 - 11 - 12
K.V. - 38 - 40 - 42 - 44 - 46

EOSPHAGUS

Spot film
100 MA. 30" Dist. Grid
65 KV - 1/10 Sec.

PORTABLE TECHNIQUE CHART

USE 10 M.A. ONLY

DEVELOPE at 65°--3 1/2 MIN.

OPERATING ROOM TECHNIQUE

CHILDREN 2 to 10 yrs. use half of NORMAL EXPOSURE

SMITH-PETERSON NAIL

	SMALL	MEDIUM	LARGE
A.P. Hip	60 KV 36" 6 sec. Grid	65 KV 36" 8 sec. Grid	75 KV 36" 10 sec. Grid
Lateral	65 KV 36" 15 sec. Grid	70 KV 36" 20 sec. Grid	75 KV 36" 25 sec. Grid

DANGER---USE TIMER AT 5 SECOND INTERVALS

KIDNEY (exposed)

70 KV 36" Dist. 2 Seconds

LUMBAR SPINE

A.P.	60 KV 36" 7 sec. Grid	65 KV 36" 10 sec. Grid	75 KV 36" 10 sec. Grid
Lateral	60 KV 36" 18 sec.	65 KV 36" 25 sec.	75 KV 36" 30 sec.

DANGER---USE TIMER AT 5 SECOND INTERVALS

DORSAL SPINE

A.P.	60 KV 36" 4 sec. Grid	65 KV 36" 6 sec. Grid	70 KV 36" 8 sec. Grid

Lateral REDUCE TIME ONE-HALF FROM ABOVE

CERVICAL SPINE

	SMALL	MEDIUM	LARGE
A.P.	60 KV 30" 2 1/2 sec.	65 KV 30" 3 sec.	65 KV 30" 3 1/2 sec.
Lateral	60 KV 36" 1 sec.	65 KV 36" 1 sec.	70 KV 36" 1 sec.

No Grid

ABDOMEN

60 KV 36" 1 sec.	68 KV 36" 1 sec.	75 KV 36" 1 sec.

No Grid

SKULL

Lateral	60 KV 30" 3 sec.	65 KV 30" 3 1/2 sec.	70 KV 30" 3 1/2 sec.
A.P.	67 KV	76 KV	77 KV + 4 sec.

JAW

Lateral 45 KV 30" Dist. 1/2 sec. No Grid

EXTREMITIES

10 M.A. 36" Dist. 1 sec. Screen
10 M.A. 36" Dist. 5 sec. No Screen
C.M. 5 6 7 8 9 10 11 12 13 14 15 16 17 18
K.V. 36 38 40 42 44 46 48 50 52 54 56 58 60

CHEST

10 M.A. 36" Dist. 2/10 sec.
C.M. 15 16 17 18 19 20 21 22 23 24 25
K.V. 58 60 62 64 66 68 70 72 74 76 78

CHILDREN 2 to 10 10 M.A. 36" Dist. 2/10 sec. 54 KV
INFANTS 10 M.A. 36" Dist. 1/10 sec. 55 KV

mimi